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Logging Damage in Thinned, Young-Growth True Fir Stands in California and Recommendations for Prevention

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Abstract

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Logging-damage surveys and tree-dissection studies were made in commercially thinned, naturally established young-growth true fir stands in the Lassen National Forest in northern California. Significant damage occurred to residual trees in stands logged by conventional methods. Logging damage was substantially lower in stands thinned using techniques designed to reduce injuries from felling and skidding. A total of 243 wounded white and red firs in 11 stands were felled, dissected, and analyzed for decay. All wounds were infected by decay fungi. Decay losses associated with wounds were 6.8 and 14.0 percent of the gross merchantable Scribner board-foot volume of the red and white firs sampled, respectively. Wound area and age were most closely related to extent of decay. Volumes of cubic- and board-foot decay are given for wounds of various sizes and ages. Recommendations are made for reducing logging damage to residual trees during thinning operations.

Keywords: Logging damage, young-growth stands, thinning effects, decay (wood), coniferae.

Summary

This paper reports the results of three related studies of logging damage in thinned, young-growth stands of true fir, Douglas-fir, and ponderosa pine in California. Two were of damage surveys made in five stands thinned using conventional logging practices and in four stands logged using procedures designed to reduce damage to residual trees. The third was of tree dissections in 11 true fir stands to relate decay losses to logging wounds. In the five conventionally thinned, young-growth stands surveyed in northern California, 22 to 50 percent of the residual trees were wounded. Of the residual trees in three of the stands, 8 to 15 percent were so badly damaged they were no longer suitable as crop trees. Surveys made in the four stands that were thinned using techniques designed to reduce logging and skidding injuries indicated that damage to residual trees was substantially reduced, ranging from 5 to 14 percent. A total of 199 white and 44 red firs bearing 301 wounds were felled, dissected, and studied in 11 stands in the Lassen National Forest. All wounds examined on the white and red firs were infected by decay fungi. Average age of thinning wounds on the white firs was 13 years. In the white firs, 4.5 percent of the gross merchantable cubic volume and 14.0 percent of the board-foot volumes were lost to decay associated with the wounds. Injury-related decay losses in the red firs were less, but not significantly different.

Present and original wound size and age were the most important characteristics related to amount of decay. Although healed wounds were older than those still open, they had less associated decay. Gouged wounds had more decay than smooth ones, and those in contact with the ground had more decay than those above the ground line.

Tables and the equations used to derive them are presented, so that cubic- and board-foot decay volumes can be determined when present wound area and injury age are known.

The best way to reduce decay losses is to avoid injury to residual trees. Procedures are recommended that will substantially reduce logging damage to residual trees and allow maximum response by the stand to thinning.

Introduction

Observations in several thinned stands of young true fir indicate that significant decay losses are associated with logging wounds, particularly injuries to the lower bole (Maloy 1979), in white fir *(Abies concolor* (Gord. and Glend.) Lindl. ex Hildebr.) and red fir *(A. magnifica* A. Murr.) in northern California. As forest management intensifies, stands will be entered and logged at younger ages, and decay associated with logging damage may lead to serious reductions in projected yields of young-growth fir stands. Forest managers need to know how much volume will be lost to decay associated with logging damage during the period between commercial thinning and harvest and how to prevent or reduce these losses.

Objectives

The primary objectives of these studies were to determine, through surveys of commercially thinned true fir, Douglas-fir, and ponderosa pine stands, the extent of logging-related wounding to residual-crop trees and, through tree dissections in true fir stands, to relate volume of decayed wood to size, age, and position of wounds relative to the ground, to compare decay losses in white and red firs; to determine damage to be expected using current thinning procedures, and to develop guidelines useful in determining allowable levels of damage for marking crop trees and for logging methods to minimize damage to residual stands of young true fir. Another objective was to determine the species of fungi that cause decay associated with logging wounds.

Methods

Selection of Stands

Surveys of logging damage and tree-dissection studies were made in commercially thinned, naturally established young-growth stands in the Lassen National Forest in northern California. Sampling was restricted to stands less than 100 years old that had been commercially thinned 3 to 25 years ago.

Damage Surveys

Surveys were made in stands of true fir, Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii),* and ponderosa pine *(Pinus ponderosa* Laws.) that had been thinned conventionally or by techniques recommended by the Silvicultural Development Unit[1] to reduce damage to residual trees. Plots of 1/40 acre were established at intervals of 1 chain along grid lines 2 to 5 chains apart, depending on the density of the stand. Thus, about 12.5 percent of the total area of the stands was sampled.

Only the best potential crop trees, based on diameter, height, and live-crown ratio in comparison to neighboring trees, in the 1/40-acre plots were examined for logging damage. Logging damage included broken tops and wounds in which bark and cambium were destroyed. In three stands, data were taken on the number of trees that were no longer potential crop trees because of severe logging damage. In two of these stands, the location of wounds on potential crop trees was also noted. Injuries were recorded as basal wounds, if they were in contact with the ground; as bole wounds, if they occurred between the ground line and the base of the live crown; and crown wounds, if they were in the live crown.

Tree Dissection

In each of 11 stands in the Lassen National Forest, 20 to 26 injured white and red fir crop trees were selected for dissection and measurement of tree and decay volumes. Trees selected for dissection were representative of the diameter and crown classes comprising the stand, and all had logging wounds of various sizes and types. Sampling was generally done in active timber sales so that merchantable portions of sample trees could be used.

Before a tree was felled, species, diameter at breast height, and crown class were recorded in addition to the following wound information: height from the ground line to the base of the wound, original and present scar width and length, scar aspect on the tree, and whether it was healed, rough (at least 25 percent of the surface of the injury was gouged), or smooth. The trees were felled and dissected; logs, internal decay, and other defects were measured according to Aho (1977), and the age of trees and wounds determined.

Identification of Fungi Associated With Decay

One or more discolored or decayed wood samples of about 3 cubic inches, depending on the size of the decay column, were taken from behind each injury. Two isolation attempts were made from each sample using aseptic techniques described by Aho (1977) to determine the causal fungi. Hymenomycetous fungi were identified by comparison with known isolates obtained from the Center for Mycology Research at the Forest Products Laboratory, Madison, Wisconsin.

Data Analysis

Cubic and Scribner board-foot volumes were calculated for trees and decay in a computer program (PACUL) on file at the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Data for trees were tabulated by stands, wound types, and decay fungi. Regression analysis was used to determine the relationship among decay (either decay volume or percent of total tree volume) and tree and wound characteristics: age and d.b.h. of the tree and age, size, condition,(healed, rough, or smooth), and position of the wound on the tree relative to the ground: Covariance analysis was used to see if, differences in decay between red and white fir and between different wound characteristics were significant.

[1] A zone silvicultural unit developing techniques for managing young-growth stands, Region 5 Timber Management, Redding, California.

Results

Table 1—Logging-damage surveys made in stands thinned conventionally

Stand name	Species	Type of logging[1]	Trees sampled	Crop trees damaged[2]	
				Wounded	No longer suitable[3]
			Number	*Percent*	
Battle	White fir	Skidder	813	22	–
Reynolds	Douglas-fir	Tractor	500	35	15
School	White fir	Skidder	719	33	–
Mad	Douglas-fir	Cable	500	46	8
Backgrass	White fir	Grapple skidder	500	50	15

-Data not available.

[1] Skidder logging used rubber-tired vehicles; tractor logging used steel-tracked vehicles.
[2] Logging damage included broken tops and wounds in which the bark and cambium were destroyed.
[3] Crop trees destroyed are included in percent-wounded figures.

Stand Damage Surveys

Damage surveys made in young-growth white fir and Douglas-fir stands thinned conventionally (including by tractor and rubber-tire skidder and by cable) indicated that significant damage occurred to crop trees (table 1). In the five stands sampled, 22 to 50 percent of the crop trees were wounded. In three stands, 8 to 15 percent of the residual trees were either killed or so badly wounded that they were no longer suitable for crop trees. The types of logging injuries to crop trees were noted in surveys made in two true fir. stands conventionally thinned using rubber-tire skidders (table 2). The locations of wounds on crop trees were consistent in both stands. Nearly three-quarters of the wounds in both stands were basal, that is, in contact with the ground. Basal wounds are more likely to become infected, and decay is usually more extensive than in wounds higher on trees.

Table 2—Location of wounds on crop trees in two true fir stands thinned

	Battle stand	School stand
Trees sampled, number	813	719
Trees damaged, number	176	239
Trees damaged, percent	22	33
Basal[1] wounds, percent	74	72
Bole[2] wounds, percent	15	16
Crown[3] wounds, percent	11	12

[1] Basal wounds were those in contact with the ground.
[2] Bole wounds occur from above ground line to the bottom of the live crown.
[3] Crown wounds occur within the live crown.

Table 3—Logging-damage surveys in stands logged using procedures designed to reduce damage to residual trees

Stand name	Species	Type of logging[1]	Crop trees damaged
			Percent
Island	Ponderosa pine	Skidder	5
Red A	White fir	Tractor	11
Red B	White fir	Tractor	11
Red F	White fir	Tractor	14

[1] Skidder logging used rubber-tired vehicles; tractor logging used steel-tracked vehicles.

Surveys made in four young-growth stands thinned using techniques designed to reduce injuries from logging and skidding showed substantial reductions in wounds on crop trees (table 3). Percent of crop trees wounded in these stands ranged from 5 to 14 percent.

Tree-Dissection Studies

Data describing the white and red firs selected for the dissection studies are given in table 4. A total of 199 white and 44 red firs were studied in the 11 stands. Tree ages and sizes (d.b.h. and height) varied widely within stands for each species, but the variation in these characteristics between species was not great. The white firs were, on the average, slightly older and larger than the red firs.

Not counting top damage, 251 wounds were found on the 199 white firs and 50 wounds on the 44 red firs sampled. Some were old fire or mechanical wounds not associated with commercial thinning. Other trees had advanced root-rot infections, which also were not associated with thinning wounds. Slightly more than 15 percent of 243 white and red firs sampled had old wounds, broken tops, or root-rot infections. Associated decay losses amounted to 5.4 and 18.1 percent of the cubic and Scribner board-foot volumes of the affected trees, respectively.

On 186 white firs, 231 thinning wounds, were found, and 44 occurred on 39 red firs (table 5). Average age of the injuries was 13 years for the white fir and 8 years for the red fir. All were infected by decay fungi. Associated with the wounds was a 4.5 percent loss of the gross merchantable cubic volume and 14.0 percent of the board-foot volume of the white fir trees. Decay accounted for 1.9 and 6.8 percent of the gross merchantable cubic- and board-foot volumes, respectively, of the red fir trees.

Factors Influencing the Amount of Decay Associated With Wounds

Covariance analysis indicated no statistically significant differences in decay associated with wounds between the white and red firs sampled. Therefore, both species were grouped to determine which scar characteristics were significantly related to associated cubic- and board-foot decay volumes. Present and original wound size and age were the most important wound characteristics related to amount of decay. Present wound size explained more variation in decay than did original wound size. Wound age and present size were used in regression analysis to develop equations that can be used to estimate cubic- and board-foot decay losses associated with thinning wounds on true firs.

No statistically significant differences were found in cubic- or board-foot volume of decay among the eight wound aspects tested by covariance analysis. Significant differences occurred in cubic-foot volume of decay and wound condition (healed, smooth, and gouged), but not between board-foot volume of decay and wound condition, probably because of the relatively small number of wounds sampled on sawtimber trees (11.0 inches d.b.h. and larger). Although healed wounds were older than those still open, they had less associated decay. Gouged wounds had the most decay.

Decay was also significantly related to position of the wound relative to the ground; wounds in contact with the ground had more decay than those originating higher in the tree.

Fungi Causing Decay

We attempted to isolate the fungi causing decay in 299 infections in the white and red fir study trees. Decay fungi were isolated from less than 28 percent of the infections (table 6), and more than two-thirds of them could not be identified. Of those identified, *Pholiota limonella* (Pk.) Sacc. was most common.

Table 4—Basic data for wounded trees dissected in 11 stands

Species	Tree basis	Age Average	Age Range	D.b.h. Average	D.b.h. Range	Height Average	Height Range
	Number	*Years*		*Inches*		*Feet*	
White fir	199	86	39-189	9.6	4.0-20.0	48	18-99
Red fir	44	84	49-131	8.8	4.1-17.4	40	14-98

Table 5—Decay data for thinning wounds in young-growth white and red firs

Species	Tree basis	Total wounds	Wounds infected	Average wound age	Average decay extent: Below base of wound	Average decay extent: Above top of wound	Cubic-foot volume: Gross	Cubic-foot volume: Decay	Scribner board-foot volume: Gross	Scribner board-foot volume: Decay
	Number		*Percent*	*Years*	*Feet*		*Merchant-able*	*Percent*	*Merchant-able*	*Percent*
White fir	186	231	100	13	1.6	2.0	2,020.0	4.5	*5,360*	14.0
Red fir	39	44	100	8	1.5	1.0	361.6	1.9	*1,020*	6.8

Table 6—Number of infections and associated decay volumes by fungi isolated from wounded white and red firs

Decay fungus	Infections: Number	Infections: Percent of total	Cubic-foot volume: Decay	Cubic-foot volume: Percent of total	Scribner board-foot volume: Decay	Scribner board-foot volume: Percent of total
Pholiota limonella (Pk.) Sacc.	19	6.4	8.3	7.5	76	8.7
Heterobasidion annosum (Fr.) Bref.	5	1.7	2.9	3.5	21	2.4
Hericium abietis (Weir ex Hubert) K. Harrison	4	1.3	3.6	3.2	70	8.0
Echinodontium tinctorium (Ell. et Ev.) Ell. et Ev.	1	.3	1.3	1.2	18	2.1
Phellinus pini var. *cancriformans* Larsen, Lombard, et Aho	1	.3	.5	.4	--	--
E. tinctorium & *Pholiota limonella*	1	.3	1.6	1.5	--	--
Unidentified basidiomycetes	49	16.4	15.6	14.0	101	11.6
None	219	73.3	76.4	68.7	585	67.2
Total	299	100.0	111.2	100.0	871	100.0

- No board-foot decay volume because infection was in a pole-sized tree.

Table 7—Cubic volume of decay by age and area of thinning wounds in second-growth white and red firs in northern California[1]

Wound age	Volume of decay when area square foot of wound is:					
	0.0	1.0	2.0	3.0	4.0	5.0
Years	*Cubic feet*					
5	0.0	0.2	0.5	0.8	1.1	1.4
10	.0	.3	.6	.9	1.2	1.5
15	.1	.4	.7	1.0	1.3	1.6
20	.3	.6	.9	1.2	1.4	1.7
25	.4	.7	1.0	1.3	1.6	1.9

[1] See Appendix for equation 1 used to derive this table.

Table 8—Scribner board-foot volume of decay by age and area of thinning wounds in second-growth white and red firs in northern California[1]

Wound age	Volume of decay when area square foot of wound is:					
	0.0	1.0	2.0	3.0	4.0	5.0
Years	*Board feet*					
5	0	3	7	10	13	16
10	3	6	9	12	15	18
15	5	8	11	15	18	20
20	8	11	14	17	20	23
25	10	13	16	19	23	26

[1] See Appendix for equation 2 used to derive this table.

Decay Volume in Relation to Wound Age and Area

Multiple regression analysis indicated that cubic- and board-foot decay volumes were significantly related to wound age and original or present wound area for white and red firs. Volume and percent of cubic- and board-foot decay that can be expected for wounds of various sizes and ages are given in tables 7 and 8. Wound area in these tables is based on the present wound dimensions because it was statistically more closely related than original wound size to the amount of associated decay. Wound area in these tables was computed by multiplying the length by the width of the wound inside the callus growth (measures the open face of the wound, not including the part that had healed). The total length and width of the wound at its widest points were measured.

Average decay volumes when wound area and age are known are shown in tables 7 and 8 for young true firs less than 20 inches d.b.h. The equations used to derive the tables are presented in the Appendix.

Discussion and Recommendations

Commercial thinning is an intensive forest-management tool commonly used in northern California to increase productivity of true fir stands. Extensive damage to residual trees is being caused by conventional logging procedures. Many residual trees are so badly damaged that they are no longer potential crop trees. A high percentage of wounds are in contact with the ground; this is particularly serious because much of the value (both quantity and quality) in a tree is in the butt log.

The best way to reduce decay losses associated with thinning wounds is to avoid injury to residual trees. Our damage surveys in stands thinned conventionally and in those thinned using procedures designed to reduce damage indicate that many wounds can be prevented. Some of these procedures have been described elsewhere (Gravelle 1977). The following procedures can be used to reduce logging damage to residual trees:

Harvest Preparation

- Restrict the logging season. Do not allow logging during the spring and early summer when sap is flowing and bark is loose. Trees are easier to wound, and injuries are often larger.

- Restrict size and type of logging equipment. Match the logging system to the topography. Use cable systems on slopes steeper than 35 percent. On more gentle terrain, track-laying or rubber-tire skidding vehicles can be used. Match size of logging equipment to size of material being removed, spac ing of crop trees, and skid-trail width.

- Mark the residual trees. Marking crop trees makes them easier to see and avoid.

• Lay out skid roads in advance of logging. This is one of the best ways to reduce logging damage. Skid trails should not be cleared wider than the skidding vehicle, preferably not wider than about 8 feet.

• Use straight-line skid-trail patterns. Sharp turns should be avoided. Straight skid trails minimize skidding distance.

• Leave buffer ("bump") trees. When possible, leave cull logs and bump trees along the edges of skid trails. Remove bump trees during the last turn.

• Limit log length. Skidding long logs or the whole bole increases the probability of damage to residual trees. Log length should be related to the spacing of the residual stand.

Sale Administration

• Communicate desired results to the contractor through training and super vision. Convince operators that damage to residual trees is unnecessary and will not be tolerated.

• Fell and skid trees on skid roads before cutting other timber; otherwise, fallers have trouble finding the skid trails and felling the timber to lead. Cut stumps in skid trails as low as possible, 3 or 4 inches, to prevent the skidder from being shunted sideways into residual trees.

• Use directional felling. Fell trees toward or away from skid trails to reduce skidder maneuvering and load pivoting.

• Limb, top, and buck trees before skidding. Limb flush to the tree bole.

• Do not thin stands of thin-barked species too heavily. Young trees and thin-barked species, such as true firs and hemlocks, should not be thinned so heavily that release shock or sunscald results.

• Treat stumps for protection against *Heterobasidion [= Fomes annosus] annosum* (Fr.) Bref. Where annosus root-rot hazard is high, stumps of pines, true firs, and hemlocks should be treated as soon as possible after trees are felled.

In summary, excessive damage can occur in stands harvested improperly. Data presented here can be used to determine the extent of decay associated with logging wounds, when size and age of wounds are known. Because no chemical or biological methods are available for protecting wounds on living trees from infection by decay fungi, significant volume losses will result. The best control is prevention. Applying our recommendations will result in residual stands with minimal damage, capable of responding to the management treatment.

Metric Equivalents

1 inch = 2.54 cm
1 foot = 0.3048 m
1 chain = 20.117 m
1 cubic foot = 0.028 32 m^3
1 acre = 0.4047 ha
breast height = 4.5 feet = 137.2 cm

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Appendix

Decay-Estimating Equations

The following multiple regression equations estimate cubic and Scribner board-foot decay volumes when wound area and age are known. Wound area was computed by multiplying the present width and length at their longest and widest points within the callus tissue. Scribner board-foot volume was calculated from a stump height of 6 inches to a merchantable-top diameter inside bark of 6 inches. For cubic volume, the top d.i.b. was 4 inches.

Table 7 was derived from equation 1 and table 8 from equation 2.

Cubic-Foot Volume Equation

$$Pc = -0.23 + 0.025 (A) + 0.29 (B)$$
$$R^2 = 0.41 \quad Sy{\cdot}x = \pm 0.63 \quad N = 276 \qquad (1)$$

Scribner Board-Foot Volume Equation

$$Pb = -2.25 + 0.49 (A) + 3.15 (B)$$
$$R^2 = 0.25 \quad Sy{\cdot}x = \pm 13.47 \quad N = 92 \qquad (2)$$

Where:

Pc = cubic-foot decay volume;
Pb = board-foot decay volume;
A = wound age in years;
B = wound area in square feet;
R^2 = the coefficient of determination or the amount of variation in decay that is explained by the variables in the equations;
$Sy{\cdot}x$ = the standard deviation about regression; and
N = the sample size.

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